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13. SUPPLEMENTARY NOTES

14. ABSTRACT

A laser speckle interferometer has been purchased with DURIP funds (F49620-98-1-0185) and supported by AASERT funding to the MURI program entitled: "Advanced Magnetic Materials for Aircraft Power Applications" (F49620-96-1-0454). This instrument has been used to measure magnetic domain patterns in Fe-Si and NiMnGa alloys. It has been integrated with a laboratory electromagnet and an automated computer control program. It is currently being used in the thesis project of Mark Storch to measure components of the magnetostriction tensor for FeCo alloys.

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Final Report

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Award Number: F49620-98-1-0185

Title: Research Instrumentation for Investigating Advanced Magnetic Materials for Aircraft Power Applications

2. Technical Objective

This equipment proposal provided funds for a laser speckle interferometer to be used in optical measurements of magnetostrictive strains. Magnetostriction is a significant source of magnetic anisotropy in FeCo alloys. These are key alloys used in the rotor assembly in the integrated power unit of the More Electric Aircraft (MEA). The goals of the MEA include operation of aircraft engines at elevated temperatures. Little is known about high temperature magnetostrictive response. The original research has been aimed at developing new spatially resolved laser interferometric techniques for magnetostriction measurements in FeCo alloys.

3/4. Status of Effort; Accomplishments

A laser speckle interferometer has been purchased with DURIP funds (F49620-98-1-0185) and supported by AASERT funding to the MURI program entitled: "Advanced Magnetic Materials for Aircraft Power Applications" (F49620-96-1-0454). The interferometer was supplied by Applied Optical Systems, at a cost of $115 K (reflecting a substantial, $30 K, university discount). This equipment has been installed and implemented in MSE facilities at CMU. The interferometer has been successfully coupled with an existing laboratory electromagnet and an oven assembly with an optical window to study magnetostriction at elevated temperatures. This technique has open up the possibility of new investigations of other important magnetostrictive materials, as well, such as Terfenol, which are of interest to the Navy. It is being used for the study of magnetostriction in FeCo Hiperco alloys.

Magnetostriction is defined as the change in shape of a material upon the application of a magnetic field. In most alloys this is a small effect, generating strain on the order of parts per million, and for most calculations can be safely neglected. However, for premiere soft magnetic materials such as equiatomic iron cobalt alloys, other sources of losses have been minimized to the point that magnetostrictive losses may become significant. Due to the small size of the effect, magnetostriction can be difficult to measure. Typically, strain gauges, with their associated problems, were the

measurement technique of choice. More recently, other techniques have been developed, but all of them are simply extensions or variations on the linear strain measurement provided by the strain gauge technique. We have used electronic speckle pattern interferometry to measure the local displacement field of a sample resulting from the application of a known field. Knowing the local displacement field it is possible to calculate the local strain tensor and possible to calculate the components of the magnetostrictive tensor from the local strain tensor.

This interferometer can be used to measure local magnetostrictive strains with unparalled spatial resolution. With an appropriately developed optical system the extraordinary possibilities for high spatial resolution can be realized (with such an optical system this device can also be used for magnetic domain imaging). Implementation involved fixing a hardware synchronization problem involving the CCD element and interfacing with a controlling computer. Software has been developed (written in Mathematica$^{@TM}$) that uses these displacements to calculate local strain tensors and an overall magnetostrictive tensor. Mark Storch (with input from Marc DeGraef) has completed a data analysis code for the study of magnetostriction by laser speckle interferometry. This program is currently in the process of being debugged.

Using the electronic speckle pattern interferometer, we have observes what appear to be domain patterns in both Fe-Si alloys as well as NiMnGa alloys. The results for NiMnGa were corroborated with Nomorski imaging on an optical microscope as part of an undergraduate research project. We have also made measurements of the magnetostrictive strains resulting from the application of a magnetic field. Currently we are dealing with the accurate measurement of magnetostriction in equiatomic FeCo alloys (in the thesis research of Mark Storch) with plans to make measurements of pure iron as well. In the case of FeCo, the observations are of the correct order of magnitude and we are working to perfect the experimental technique so as to be able to extract magnetostrictive tensor values.

5. Personnel Supported

None with the funds provided from this equipment grant. M. Storch has been funded with AASERT funding to work on the implementation of this piece of equipment.

6. Publications

Measurement of Magnetostrictive Tensor Components using Electronic Speckle Pattern Interferometry (ESPI), M. L. Storch, A. D. Rollett, M. E. McHenry; 2000 Intermag Meeting – November, 1999 San Jose, to appear in IEEE Transactions on Magnetics.

7. Interactions/Transitions

The laser speckle interferometer has been used in the CMU Materials Science and Engineering senior project research of Robert Barry entitled *"Magnetic Characterization of $Ni_2MnGa(Al)$"* and supervised by Marc De Graef.

8. New Discoveries

None

9. Honors/Awards

None

10. Summary

A laser speckle interferometer has been purchased with DURIP funds (F49620-98-1-0185) and supported by AASERT funding to the MURI program entitled: "Advanced Magnetic Materials for Aircraft Power Applications" (F49620-96-1-0454). This instrument has been used to measure magnetic domain patterns in Fe-Si and NiMnGa alloys. It has been integrated with a laboratory electromagnet and an automated computer control program. It is currently being used in the thesis project of Mark Storch to measure components of the magnetostriction tensor for FeCo alloys.